



Resource Department

GEOPHYSICS AND GEOMECHANICS

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The primary focus of the Geophysics and Geomechanics Department is to develop new methodologies for extracting subsurface properties, including fluid properties, saturation, porosity, pore pressure, permeability, and in situ stress, and apply these methodologies to field data. These new methodologies incorporate a variety of data, including geophysical (seismic, electromagnetic (EM), electrical, seismo-electric, gravity, ground-penetrating radar (GPR), geomechanical (displacement, tilt), and fluid flow (pressure). Fundamental and applied research carried out in support of this objective includes laboratory rock physics and pore-scale imaging studies, field geophysics surface and borehole studies, field geophysical-imaging hardware development, theory development, computational geophysics and geomechanics modeling, and imaging and inversion (deterministic and stochastic) algorithm development. The driver for this research is the increasing need to directly image fluid saturations, pore pressures, and permeability in the subsurface for energy production, environmental remediation, carbon management, and nuclear waste disposal purposes, and to do so in the presence of anisotropy and multiscale heterogeneities.

SCIENTIFIC RESEARCH AREAS

The department is organized into five scientific research areas, led by the indicated Research Area Leaders:

- Computational Geophysics (*Don Vasco*)
- Rock Physics and Coupled Dynamics (*Seiji Nakagawa*)
- Hydrogeophysics (*Susan Hubbard*)
- Characterization and Monitoring Geophysical Instrumentation (*Ki-Ha Lee*)
- Computational Geomechanics (*Jonny Rutqvist*)

The primary purpose of these research areas is to advance the science supporting high-resolution methods for extracting subsurface properties and process information from geophysical, geomechanical, and fluid flow data.

COMPUTATIONAL GEOPHYSICS

The focus of this research area is to develop efficient, 3D numerical codes for modeling seismic wave propagation and electromagnetic wave propagation and diffusion. The challenge is to develop accurate and efficient computer codes capable of modeling the seismic and electromagnetic response of complex geologic structures (i.e., structures that may contain anisotropy or multiscale heterogeneities in the form of fractures, faults, folds, layers, or patchy saturation). A variety of methods, including boundary integral equation, global matrix, finite difference, spectral element, discrete element, and asymptotic ray methods, are in the process of being developed for high-performance parallel computing frameworks. These codes will serve as the computational engines for the next generation of modeling-based deterministic and stochastic inversion algorithms. This research is performed using the supercomputers at the National Energy Research Scientific Computing Center (NERSC) at Berkeley Lab, and the PC cluster maintained by the Center for Computational Seismology (CCS), within Berkeley Lab's Earth Sciences Division.

ROCK PHYSICS AND COUPLED DYNAMICS

The connections between a geophysical observable, such as seismic velocities and attenuation, electrical conductivity, and dielectric constant, and rock properties, such as porosity, permeability, and fluid saturation, are provided by rock-physics measurements and/or theories. Rock-properties measurement efforts are carried out at the Rock and Soil Physics Lab. This facility has the electronic instrumentation and mechanical equipment to perform a variety of geophysical measurements, including seismic, electrical, electromagnetic, and fluid flow, under low to moderate confining pressures. Experiments that require detailed information about the porous microstructure and fluid saturations at the pore level are carried out using the x-ray computed tomography (CT) scanner in the Rock Imaging

Lab and the recently completed high-resolution x-ray microtomography station located at Berkeley Lab's Advanced Light Source, and using the focused ion beam (fib) located at Berkeley Lab's National Center for Electron Microscopy. The primary focus of our laboratory efforts is towards the understanding of the geophysical properties of rock and sediments that are either not well described by conventional rock physics theories (e.g., poorly consolidated sands and clays, gas hydrates, fractured rock) or that have yet to be fully exploited (e.g., seismic attenuation, seismo-electric response). Complementary theoretical efforts are also under way to explore the dynamics of poroelastic and seismoelectric response of rocks that contain multiple fluid phases.

HYDROGEOPHYSICS

Research in the area of hydrogeophysics combines the disciplines of geophysics and hydrogeology to develop new approaches for characterizing the shallow subsurface over a range of scales for subsurface properties (such as hydraulic conductivity, geochemical heterogeneity, lithology, and moisture movement over time). This interdisciplinary field is unique in the level of fusion between hydrogeological and geophysical data sets, the incorporation of complex petrophysical models, and the application of emerging stochastic inversion techniques. In this area, new research is also being carried out to investigate the role of biogeochemical changes associated with bioremediation in the hydrological and geophysical responses resulting from processes such as dissolution/precipitation of minerals, gas evolution, and biofilm generation.

CHARACTERIZATION AND MONITORING GEOPHYSICAL INSTRUMENTATION

The focus of this research area is the development of innovative geophysical instrumentation, including sensors,

sources, and analysis software, for subsurface imaging and monitoring. Efforts that are currently under way include the development of an optimum electromagnetic system for detecting and identifying unexploded ordnance, a novel electromagnetic imaging system (for environmental applications) that operates in the frequency band between electromagnetic diffusion and wave propagation, and a miniature rotary shear source for crosswell and single-well seismic imaging applications.

COMPUTATIONAL GEOMECHANICS

This research area is concerned with the development of new computational tools for predicting stress-induced changes in transport properties, fracturing, and fault slip resulting from fluid injection, fluid withdrawal, and thermal loading. Of particular interest is the development of new computational geomechanics-based inverse methods for estimating subsurface fracturing and fluid movement, and for predicting the seismic response resulting from fluid injection into fractured rock.

FUNDING

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